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Plasmaspheric material at the reconnecting magnetopause

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Abstract. During geomagnetic storms, cold and dense plasmaspheric material is observed to drain toward the dayside magnetopause when the solar wind pressure is strong and the interplanetary magnetic field (IMF) is southward. What is the fate of draining plasmaspheric material at the magnetopause? Does the plasmaspheric material participate in the dayside reconnection and then convect on open field lines through the polar cap? Or does the material become captured into the low-latitude boundary layer and then convect on closed field lines around the flanks of the magnetosphere? In this paper, we present observations from the Los Alamos magnetospheric plasma analyzers (MPA) onboard five satellites at geosynchronous orbit during 86 plasmaspheric drainage events. For a set of events where cold plasmaspheric material is observed immediately adjacent to the magnetopause/low-latitude boundary layer, we examine the detailed ion distributions, from ~1 eV to ~40 keV, for evidence that the draining plasmaspheric ions and the entering magnetosheath ions are simultaneously present on the same flux tube. Ten cases out of 57 are found where magnetosheath ions and plasmaspheric ions were unambiguously present simultaneously in the same flux tube, which is a signature that the plasmaspheric flux tubes do experience dayside reconnection. An additional ten cases strongly, but not as definitively, support this conclusion. Further, six of seven events with available IMF information have velocity space signatures that are consistent with expectations based on the reconnection process.

1. Introduction

Under quiet conditions, magnetic flux tubes in the outer plasmasphere remain on closed drift paths for several days before becoming fully refilled with ionospheric plasma. During geomagnetic storms, when the magnetospheric convection is strong, the magnetic flux tubes are on open drift paths. When the solar wind pressure is strong and the interplanetary magnetic field (IMF) is southward, cold, dense plasmaspheric material is observed to drain toward the dayside magnetopause and is detected immediately adjacent to the magnetosheath and/or low-latitude boundary layer (LLBL) [*Elphic et al.,* 1996; *Borovsky et al.,* 1997a, 1998]. What is the fate of the cold dense plasmaspheric ions on these open drift paths? Does the plasmaspheric material participate in the dayside reconnection and then convect over the polar cap? Or is it swept into the low-latitude boundary layer and then carried along the flanks of the magnetosphere?

Freeman et al. [1977] proposed that plasmaspheric ions, reflected and accelerated at the magnetopause, funnel down into the cusp, bounce at their magnetic mirror points, and move back up along the field lines; meanwhile, the field lines convect tailward. *Elphic et al.* [1997] used a combination of empirical models of high-latitude convection and the geomagnetic field to follow the transport from the outer plasmasphere out to the magnetopause, over the polar cap and into the tail.

Low-density cold ion beams (of magnetospheric origin) were observed by ISEE 1 and 2 [*Gosling et al.,* 1990b] together with the magnetosheath ions at the low-latitude boundary layer during reconnection events. The cold-ion-beam speed parallel to the magnetic field was always less than that of the transmitted magnetosheath ions, yet both populations shared the same convective drift. Composition measurements at the Earth's dayside magnetopause by AMPTE/CCE [*Fuselier et al.,* 1991, 1993; *Fuselier,* 1995] showed evidence for reflection and transmission of magnetospheric (He^+) and magnetosheath (He^{++}) ion species. The cold ions observed in these early studies under more typical magnetopause crossing conditions were most likely part of the dayside trough [*Thomsen et al.,* 1998], rather than the dense draining plasmasphere. There is reason to question whether the more heavily loaded plasmaspheric flux tubes would similarly participate in the dayside reconnection process: Roughly speaking, the reconnection rate is proportional to the local Alfén speed, which decreases with increasing plasma density. Hence dayside reconnection might be more likely to occur for flux tubes containing low-density plasma than for more heavily loaded flux tubes, i.e., the draining plasmasphere.

In this paper, we analyze 57 events where cold dense plasmaspheric material was observed immediately adjacent to the magnetosheath/LLBL when the magnetopause was compressed to inside of ~6.6 R_E during a geomagnetic storm. Do the plasmaspheric flux tubes experience dayside reconnection? The purpose of this paper is to examine the detailed ion distributions for evidence that the draining plasmaspheric ions and the entering magnetosheath ions are simultaneously present on the same flux tube.

2. Theoretical Prediction

In the dayside reconnection scenario sketched in Figure 1 [after *Gosling et al.,* 1990a, Figure 1], magnetosheath plasma crossing the magnetopause into the low-latitude boundary layer

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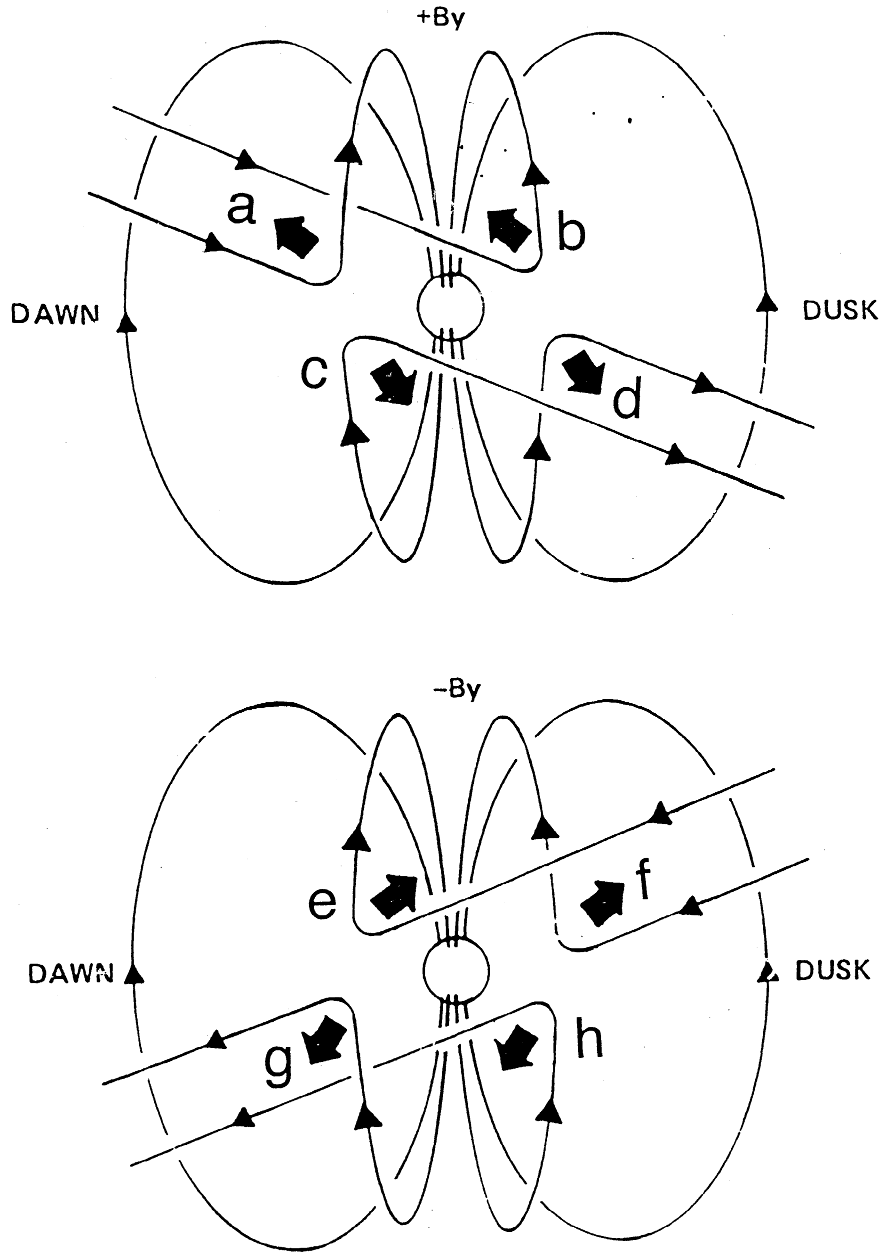

Figure 1. Schematic drawings of reconnection at the dayside magnetopause as viewed from the sun [*Gosling et al.,* 1990a]. The large arrows indicate the direction of the forces associated with magnetic tension on recently reconnected field lines.

should experience an acceleration in the direction of the large arrows. When the y component of the IMF (B_Y) is positive, the locations marked "a," "b," "c," and "d" (Figure 1, top) indicate the flow directions in the northern dawn, northern dusk, southern dawn, and southern dusk quadrants, respectively. When B_Y is negative (Figure 1, bottom) the flow direction in the northern dawn, northern dusk, southern dawn, and southern dusk quadrants, respectively, are labeled "e," "f," "g," and "h." A schematic drawing of the ion distributions in the deHoffmann-Teller (dHT) velocity space reference frame [*deHoffmann and Teller,* 1950] is shown in Figure 2, where Figures 2a and 2b show distributions expected on the magnetosheath side, while Figures 2c and 2d present the expectations for the magnetospheric side. For this example, B_Y is positive and the measurement point is taken to be in the northern dawn quadrant, corresponding to location "a" in Figure 1. In Figures 2a and 2c, the northward direction of ion flow is along the vertical axis, and the horizontal axis represents the ion flow perpendicular to the magnetopause surface, with positive V_{perp} toward the magnetosheath and negative V_{perp} toward the magnetosphere. In Figure 2b and 2d, the northward and westward directions of flow (note the reversal relative to Figure 1) are along the vertical and horizontal axes, respectively. Both panels are tangential to the local magnetopause as viewed from the Earth. The center of the spacecraft frame is marked by a plus symbol in all four panels. In Figures 2a and 2b, the ellipses represent the distribution of the incident magnetosheath ions; in Figures 2c and 2d, the small circles represent the distribution of the incident plasmaspheric ions (PS), and the larger ellipses represent the distribution of the transmitted magnetosheath ions (Msh). The construction of the ion distributions in Figure 2 is based on the reconnection theory by *Cowley* [1982, 1995] and described as follows:

The dHT frame is defined to move parallel to the magnetopause surface in such a way that the incident magnetosheath flow is field-aligned. Hence, on the magnetosheath side of the magnetopause (Figures 2a and 2b), the magnetosheath flow must lie along a field line that passes through the origin of the dHT velocity space. Figure 2 is constructed for a location that is north of the reconnection site, so the magnetosheath field should have an inward-pointing normal component (Figure 2a; we assume that the reconnection occurs under the condition of southward interplanetary field at the "nose" of the magnetopause, where the flow diverges). Moreover, the normal component of the incident flow must also be inward (to enter the magnetosphere along the field), producing the configuration shown in Figure 2a. Application of these requirements thus leads to conclusion that the incident flow is southward in the dHT frame. In a spacecraft frame at rest with respect to the magnetosphere, the magnetosheath flow is assumed here to be everywhere away from the nose of the magnetopause, i.e., northward in the northern hemisphere. Thus, the origin of spacecraft frame of reference in Figure 2a is located at zero normal velocity and slightly southward of the incident magnetosheath.

Figure 2b shows the same (magnetosheath) distribution as Figure 2a, projected into the V_{North}–V_{West} plane. The V_{North}–V_{West} plane is tangential to the local magnetopause. For positive IMF B_Y the magnetosheath field points in the eastward direction and again passes through the magnetosheath flow and the dHT origin. The northward component of velocity of both the magnetosheath flow and the spacecraft frame is the same as in Figure 2a, and the flow is field-aligned in the dHT frame, so the incident flow must be southward and eastward in the dHT frame, as shown in Figure 2b. In the spacecraft frame the flow on the dawn side of the nose is dawnward (westward), so the spacecraft frame must be somewhat east of the magnetosheath flow (Figure 2b).

Just inside the magnetopause (Figures 2c and 2d), the dHT frame is the same, so the origin of the spacecraft frame in Figures 2c and 2d is the same in Figures 2a and 2b. Similarly, the reconnected magnetospheric field must have an inward normal component and be generally northward (as it is dominated by the Earth's dipole field). The transmitted magnetosheath population is field-aligned again, with the same speed as the incident mag-

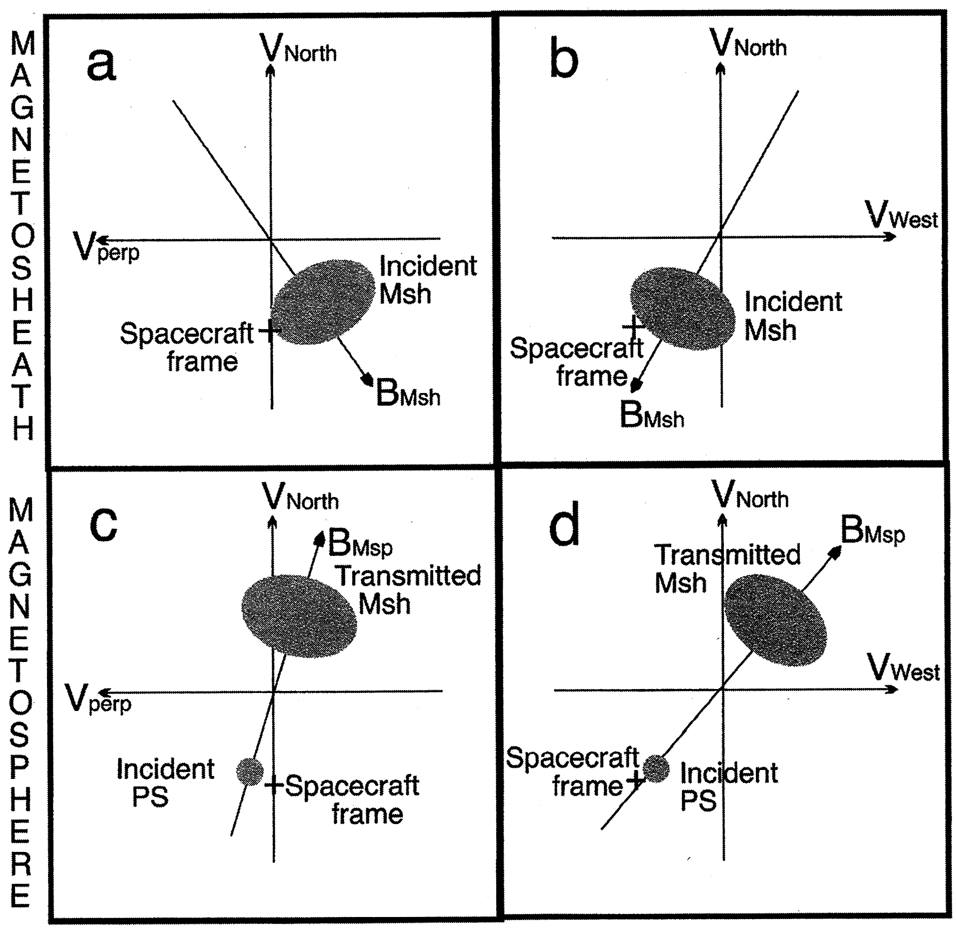

Figure 2. Schematic drawing of the ion distributions in the deHoffmann-Teller velocity space reference frame. (a, b) Distributions expected on the magnetosheath side; (c, d) the expectations for the magnetospheric side. In Figures 2a and 2c, the northward direction of the ion flow is along the vertical axis. The horizontal axis represents the ion flow along the magnetopause normal, where left is toward to the magnetosheath and right is toward to the magnetosphere. In Figure 2b and 2d, northward and westward directions of the ion flow are along the vertical and horizontal axes, respectively. The view is from the Earth, and both panels are tangential to the local magnetopause. See text for detailed descriptions.

netosheath. Thus it should be flowing northward and inward in the dHT frame (Figure 2c). Moreover, in the dHT frame the incident cold plasmaspheric ions should also be moving along the field, in the direction opposite to the transmitted magnetosheath. Since our satellite observations show that the incident cold ions typically have only a small velocity relative the spacecraft, they are placed near the origin of the spacecraft frame in Figure 2c.

In the V_{North}–V_{West} projection (Figure 2d) the northward component of flow for both populations must be the same as in Figure 2c. For most of the events we have observed, the cold ion flow is found to be slightly westward in the spacecraft frame, and the field is generally inclined toward the west, resulting in the placement shown in Figure 2d. Finally, with the requirement that the transmitted magnetosheath population be field-aligned in the dHT frame, the full configuration of Figure 2d is determined.

On the magnetosheath side of the reconnection, two other populations, reflected magnetosheath and transmitted plasmaspheric ions, might exist. However, it is difficult to identify them using our data presented in this paper; hence both populations are neglected from the drawing shown in Figures 2a and 2b. Transmitted plasmaspheric ions would gain sufficient energy through the reconnection process so that the energized plasmaspheric ions and magnetosheath ions would be indistinguishable by their energies. Since the measurements used in this paper do not provide us with information on the ion composition, studies of transmitted magnetospheric ions on the magnetosheath side are difficult. Reflected plasmaspheric ions are difficult to observe on the magnetospheric side for the same reason. Even if these reflected ions exist, they would be mixed with the transmitted magnetosheath ions, making them difficult to identify. In an effort to keep things simple and to make the comparison with data easier, we have not included a reflected plasmaspheric population in the predicted distributions (Figures 2c and 2d).

Corresponding to the conditions measured at locations "b"–"h" in Figure 1, expected ion distributions at the magnetopause reconnection can be constructed in a manner similar to that described above. The predictions will serve as our basic guide for interpreting the observed ion distributions.

3. Geosynchronous Observations

The data shown in this paper were obtained by Los Alamos magnetospheric plasma analyzers (MPAs) on satellites 1989-046, 1990-095, 1991-080, 1994-084, and LANL-97A, operating at geosynchronous orbit (6.6 R_E). In Figure 3, a sketch is shown of the location of a geosynchronous satellite during an interval of strong compression and erosion. The gray area represents the draining plasmasphere. The dashed line represents the location of the magnetopause under conditions of strong compression and erosion, while the dotted line represents the location of the magnetopause during normal solar wind conditions.

The MPAs are spherical sector electrostatic analyzers that measure the three-dimensional velocity space distributions of ions and electrons over the nominal energy per charge range of ~1 V to 40 kV. A sequence of two- and three-dimensional ion and electron distributions is measured every 86 s, with each three-dimensional (40 energies x 24 azimuths x 6 polar angles) distribution function being measured during a single 10-s spin of

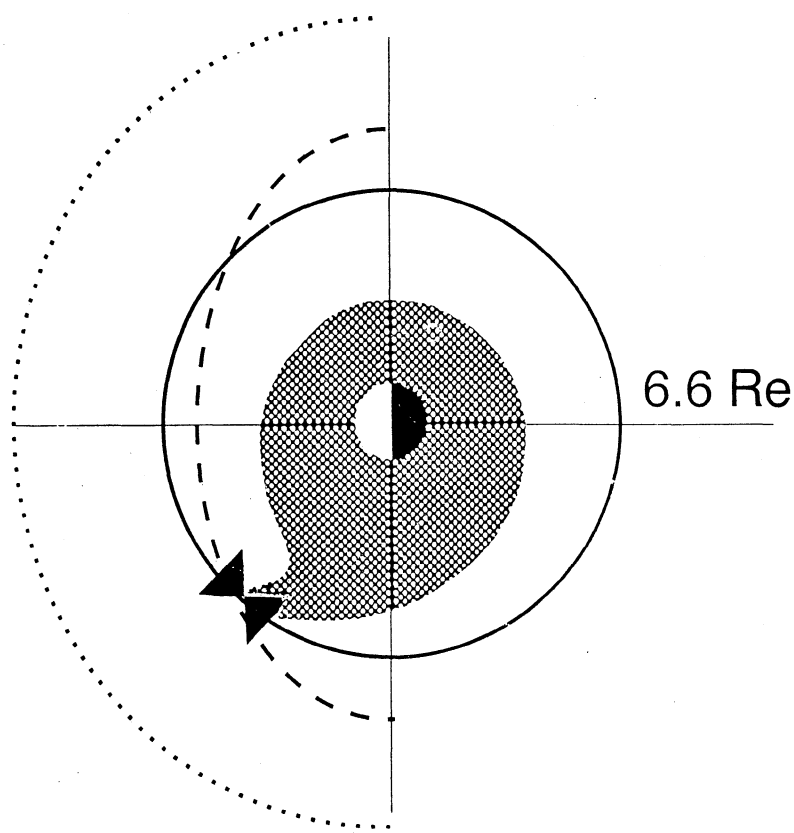

Figure 3. A schematic drawing of the location of a geosynchronous satellite during an interval of strong compression and erosion. The dotted line represents the location of the magnetopause during normal solar wind conditions, while the dashed line represents the location of the magnetopause during a geomagnetic storm.

the satellite. The spin axis of the spacecraft points continuously at the center of the Earth, so the two polar angle detectors that view nearly perpendicular to the spin axis (belly-band channels) give very complete pitch angle coverage. The two-dimensional ion distributions shown in this paper are plotted using the data measured by these two belly-band polar detectors. Further details on the instrument are provided by *Bame et al.* [1993]. Typical examples of the observations at geosynchronous orbit have been presented by *McComas et al.* [1993]. Information about the direction of the magnetic field at the satellites is obtained by determining the orientation of the symmetry axis of the three-dimensional distribution functions, i.e., the eigenvector associated with the parallel temperature of ions or electrons [*Thomsen et al.*, 1996]. The uncertainty of the orientation of the magnetic field increases particularly in the magnetosheath/LLBL. In our study, the magnetic field orientation assists us in comparing observed distributions with predictions. In addition to the MPA data, Wind plasma and magnetic field data in the solar wind are also utilized. The IMF information is obtained from either Wind or IMP 8 (before 1994).

The detailed description of MPA observations of magnetopause crossings at geosynchronous orbit has been presented by *McComas et al.* [1994]. Table 1 lists all of magnetopause crossing events identified for the present study from MPA data from the five satellites between January 1991 and December 1998. "Msh-PS" indicates events where plasmaspheric ions were observed immediately adjacent to the magnetosheath plasma. "Msh" indicates events where dense plasmaspheric ions were not found adjacent to magnetosheath ions. "Msh&PS*" indicates events where magnetosheath and plasmaspheric ions could be conclusively identified in the same flux tube as discussed below. "Msh&PS?" indicates events where both magnetosheath and plasmaspheric ions were observed within the same 10-s snapshot, but time-aliasing could not be conclusively ruled out, which will be discussed in section 4. Few magnetopause-crossing events were found during 1995-96 due to the existing solar minimum conditions. We now examine two typical events in detail using spectrograms and ion distributions.

3.1. Event of May 15, 1997

Plate 1a shows ion energy-time spectrograms for the southward and eastward look directions and an electron spectrogram for the eastward look direction from 0600 to 0900 UT on May 15, 1997, as measured by MPA 1991-080. The open triangles indicate local noon and the particle counts are color-coded according to the log scale shown on the image. The ion plasma sheet, with energy above ~10 keV, appears at the top of the ion spectrograms. Magnetosheath-like ions, with energies of the order of 1 keV, were observed at ~ 0715, 0734-0740, and 0744 UT. Cold dense plasmaspheric ions, with energies of the order of 10 eV and moving primarily westward (and thus seen in the eastward look direction), were observed adjacent to the magnetosheath ions. There are two ion populations in the LLBL at 0744 UT as indicated by the red arrow in Plate 1a: one is a hot magnetosheath ion population; the other is a plasmaspheric ion population. This plasmaspheric ion population is at higher energies than the plasmasphere for the other times, which may indicate an energization through the reconnection process.

On May 15, 1997, Wind observations showed that the solar wind density was high (> 20 cm^{-3}) from 0000 to 0800 UT and the IMF was southward from 0500 to 0730 UT (not shown here), providing the strong dynamic pressure and erosion needed to push the magnetopause to geosynchronous orbit. Taking into account the time delay, the magnetopause crossing at 0744 UT at geosynchronous orbit would have been under conditions of southward ($-B_Z$) and dawnward ($-B_Y$) IMF. A two-dimensional ion phase-space-density distribution measured by MPA 1991-080 at 0744 UT (1222 LT) is shown in Plate 2a, corresponding to the red arrow shown in Plate 1a. The positive y and positive x axes are in the northward and westward directions of the ion flow, opposite from the satellite look directions in the spectrograms. The phase space densities are color-coded according to the color bar with log scale. The predicted ion distributions on the magnetospheric side of the reconnection are shown in Plate 2c, corresponding to the conditions at location "f" in Figure 1. The format of Plate 2c is similar to that in Figure 2d; however, it is shifted to the spacecraft frame rather than the dHT frame for comparison with observed distributions. There are two ion populations detected simultaneously in Plate 2a: one is the cold incident plasmaspheric ion distribution flowing westward and northward, the other, the hot transmitted magnetosheath ion distribution flowing slightly eastward and northward. For this case, the moments were not computed [*Thomsen et al.,* 1999]; hence we do not have the information of the magnetic field direction. However, if the magnetosheath and plasmaspheric ions have the same $E \times B$ convection velocity, the two populations should both lie along the magnetic field; hence we still consider observed distributions agree with the prediction in Plate 2c. In Plate 2a, there are nine consecutive energy sweeps (each requiring 423 ms and covering 15° of spin) in which cold ions were observed simultaneously with magnetosheath ions, which is the evidence that both ion species were present in the same flux tube.

3.2. Event of August 27, 1998

Ion spectrograms for the northward and eastward look directions, and an electron spectrogram for the eastward look direction from 0700 to 1000 UT on August 27, 1998, as measured by MPA LANL-97A are displayed in Plate 1b. The format is the same as that described earlier for Plate 1a. Plasmaspheric ions, with an energy of the order of 10 eV, were observed to flow mainly westward (seen in the eastward look direction), and plasma sheet ions with energies of the order of 10 keV were observed in all directions. Magnetosheath-like ions with energies of the order of 1 keV were seen at ~0807, 0812, and 0814-0816 UT, adjacent to the cold dense plasmaspheric ions. There are two ion populations in the LLBL at 0807 UT, as indicated by the red arrow in Plate 1b: one is a hot magnetosheath ion population, and the other is a plasmaspheric ion population. This plasmaspheric ion population appears to be energized to a level comparable with that of the lowest energy level seen in the magnetosheath population. In spite of this, these plasmaspheric ions are still distinguishable in the spectrogram and distribution plots.

The magnetopause crossing at 0807 UT was caused by a solar wind density (pressure) enhancement observed by Wind from 0700 to 0800 UT (not shown here). The IMF was southward on Wind after ~0635 UT. The y component of the IMF was positive during 0730-0748 UT. Taking into account the time delay, the magnetopause crossing at 0807 UT at geosynchronous orbit would have been under conditions of the southward ($-B_Z$) and duskward ($+B_Y$) IMF. In this case, the satellite location would have been below a subsolar reconnection point (location "d" in Figure 1) because the sunward tilt of the Earth's axis in summer puts geosynchronous orbit below the ecliptic plane on the dayside. A two-dimensional ion phase-space-density distribution

Table 1. Magnetopause Crossing Events

Date	1989-046	1990-095	1991-080	1994-084	LANL-97A
March 24, 1991	Msh&PS?	Msh-PS			
March 25, 1991	Msh-PS	Msh			
March 26, 1991		Msh-PS			
June 1, 1991		Msh-PS			
June 4, 1991	Msh&PS*				
June 5, 1991	Msh-PS	Msh			
June 9, 1991	Msh&PS?	Msh			
June 10, 1991	Msh				
June 11, 1991	Msh-PS	Msh-PS			
June 12, 1991	Msh				
June 13, 1991		Msh-PS			
June 17, 1991	Msh				
July 8, 1991	Msh				
July 13, 1991	Msh				
August 19, 1991		Msh&PS?			
October 1, 1991	Msh				
October 28, 1991	Msh				
October 29, 1991		Msh&PS*			
October 31, 1991	Msh				
November 1, 1991	Msh				
November 8, 1991	Msh				
November 9, 1991		Msh-PS			
November 11, 1991	Msh				
November 21, 1991	Msh				
February 2, 1992	Msh				
February 3, 1992		Msh			
February 9, 1992	Msh-PS		Msh&PS?		
February 20, 1992		Msh&PS*	Msh-PS		
February 21, 1992		Msh	Msh-PS		
February 26, 1992	Msh				
February 27, 1992	Msh-PS		Msh-PS		
March 17, 1992	Msh-PS				
May 10, 1992		Msh&PS*			
August 22, 1992	Msh&PS?				
August 23, 1992	Msh-PS		Msh		
September 9, 1992		Msh&PS?			
September 17, 1992		Msh			
November 1, 1992	Msh-PS				
December 7, 1992		Msh-PS			
March 8, 1993	Msh				
March 9, 1993	Msh-PS		Msh&PS?		
April 4, 1993	Msh&PS?				
November 3, 1993	Msh&PS?				
November 4, 1993	Msh&PS*				
November 18, 1993		Msh-PS			
December 1, 1993		Msh-PS			
February 5, 1994	Msh-PS				
February 6, 1994	Msh&PS?				
February 21, 1994	Msh	Msh			
October 29, 1994		Msh-PS			
April 7, 1995		Msh-PS			
January 10, 1997				Msh-PS	
February 8, 1997		Msh&PS*			
May 15, 1997			Msh&PS*		
May 2, 1998			Msh-PS		
May 3, 1998			Msh	Msh-PS	Msh-PS
May 4, 1998			Msh	Msh-PS	Msh-PS
July 16, 1998				Msh-PS	Msh-PS
August 6, 1998				Msh-PS	Msh&PS?
August 27, 1998			Msh	Msh	Msh&PS*
September 25, 1998				Msh-PS	Msh&PS*
October 19, 1998				Msh-PS	Msh
November 8, 1998				Msh&PS*	Msh&PS*

Msh, magnetosheath ions; PS, plasmaspheric ions.

measured by MPA LANL-97A at 0807 UT (1245 LT) is shown in Plate 2b, corresponding to the red arrow shown in Plate 1b. The format of Plate 2b is the same as that of Plate 2a. The short dashed line is the estimated magnetic field direction, determined by the orientation of the symmetry axis of the three-dimensional ion distribution function. The predicted ion distributions inside the reconnection magnetopause are shown in Plate 2d, corresponding to the conditions at location "d" in Figure 1. The format of Plate 2d is similar to that in Plate 2c. There are two ion populations sharing the same convection drift in Plate 2b: one a cold incident plasmaspheric ion distribution flowing slightly westward and southward; the other, a hot transmitted magnetosheath ion

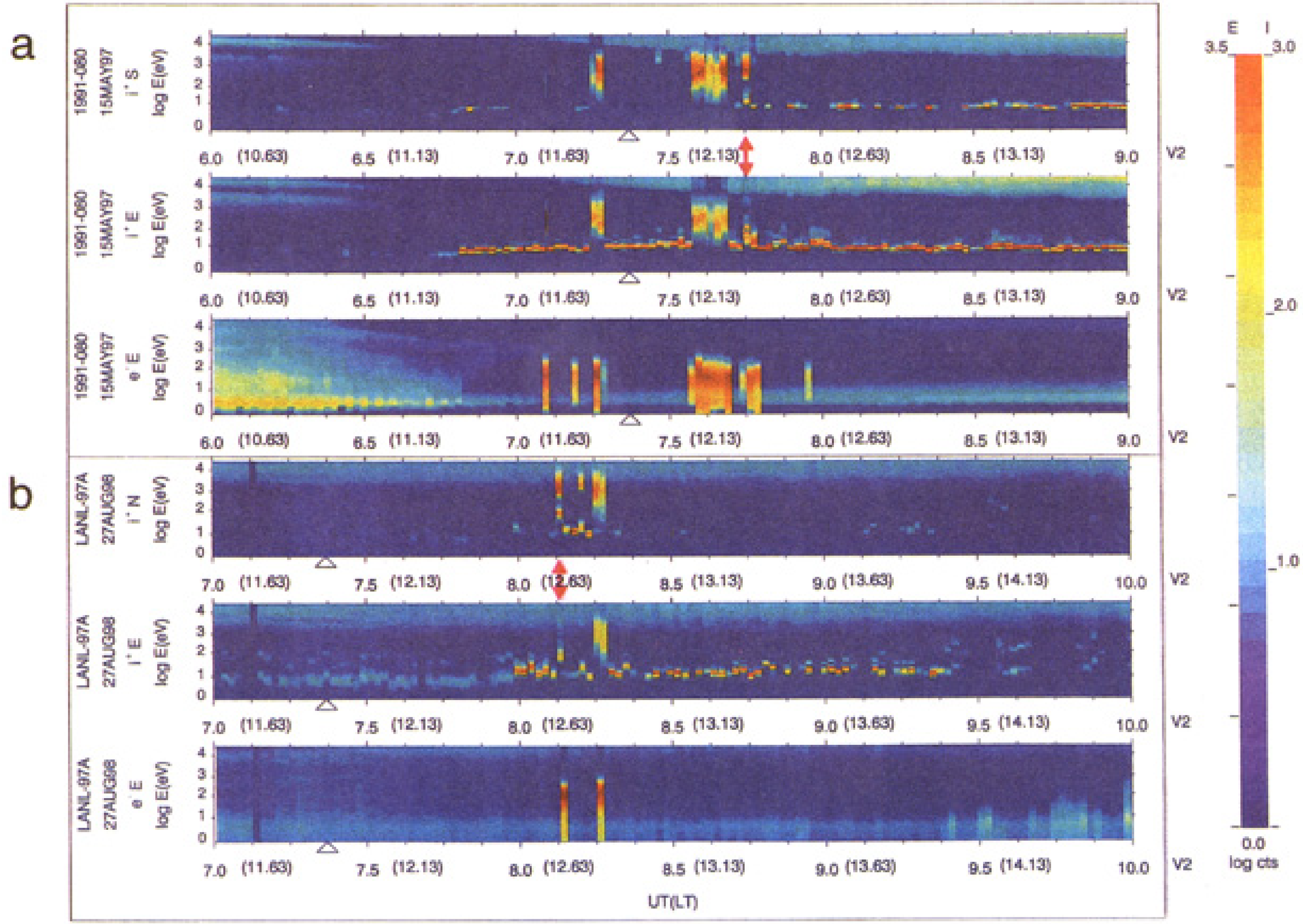

Plate 1. (a) Ion energy-time spectrograms in the south and east satellite look directions and electron spectrogram in the east look direction from 0600 to 0900 UT on May 15, 1997, by MPA 1991-080. (b) Ion energy-time spectrograms in the north and east satellite look directions and electron spectrogram in the east look direction from 0700 to 1000 UT on August 27, 1998, by MPA LANL-97A. Universal time and local time (in parentheses) are indicated along the horizontal axis. The log of the particle count rate is color coded. The open triangles represent local noon.

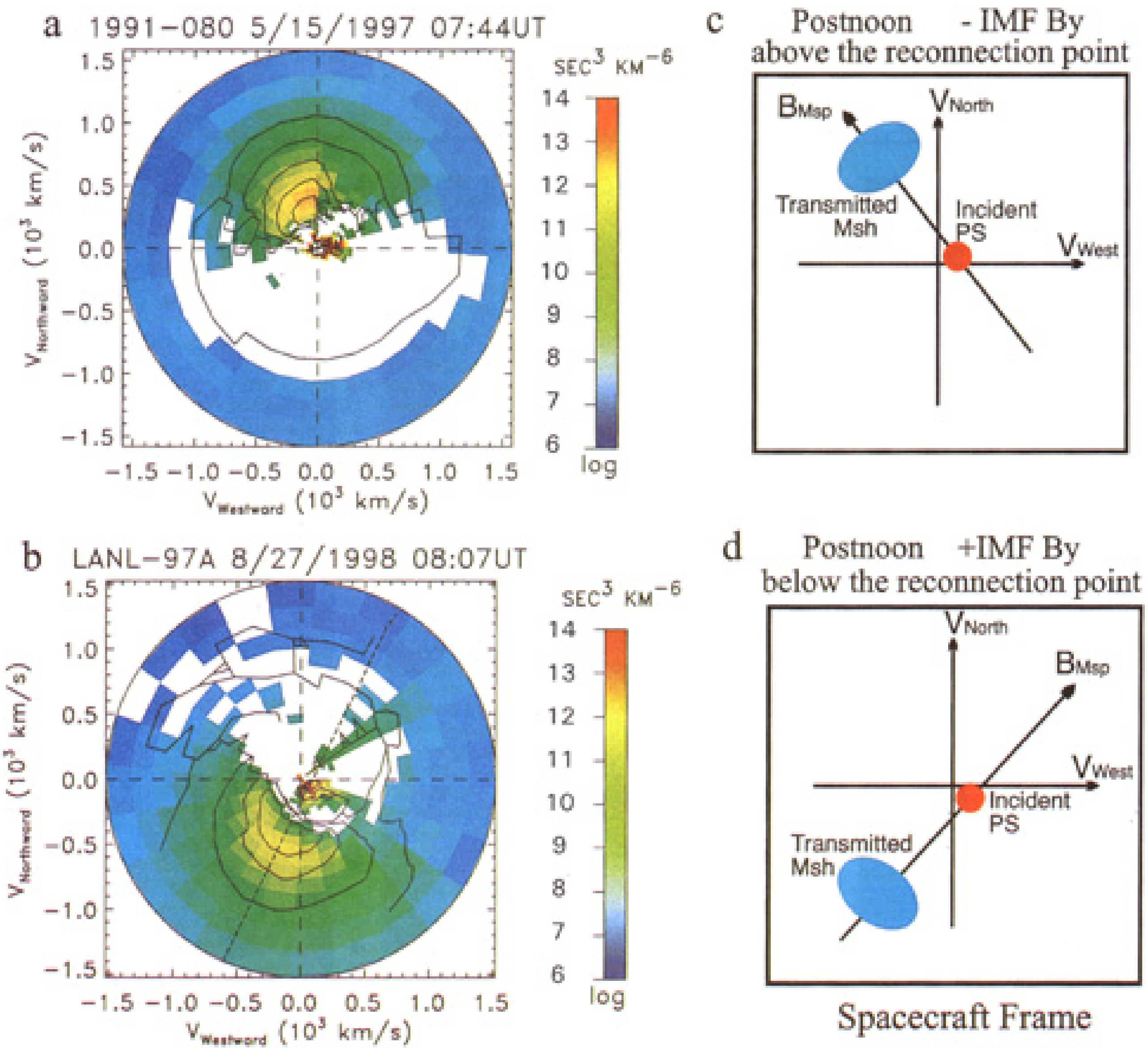

Plate 2. Ion phase space density distribution functions (a) at 0744 UT (1222 LT) observed by MPA 1991-080 and (b) at 0807 UT (1245 LT) observed by MPA LANL-97A, corresponding to the red arrows in Plate 1a and 1b, respectively. The positive y and positive x axes are in the northward and westward directions of the ion flow, respectively. The phase space densities are colored based on the color bar with log scale. (c, d) Predicted distributions inside the magnetopause during the reconnection at locations corresponded to the conditions marked "f" and "d" in Figure 1, respectively. The format of Plates 2c and 2d is similar to that in Figure 2d; however, it is shifted to the spacecraft frame rather than the dHT frame for comparison with Plates 2a and 2b.

distribution flowing eastward and southward. These observed ion distributions agree with our expectation from the prediction. In Plate 2b, there are four consecutive energy sweeps in which cold ions were observed simultaneously with magnetosheath ions, which is the evidence that both ion species were present in the same flux tube.

4. Discussion and Conclusion

A total of 86 magnetopause-crossing events from five geosynchronous satellites from January 1991 through December 1998 are listed in Table 1. In our examination of 57 events where cold plasmaspheric material was observed immediately adjacent to the magnetopause/LLBL, 10 cases were discovered in which plasmaspheric ions appeared simultaneously with magnetosheath-like plasma, as indicated by the presence of both species within at least two 423-ms sweeps (covering over 30° of spin) of the analyzer voltage. These unambiguous events are identified by "Msh&PS*" in Table 1. In another 10 of the 57 cases, plasmaspheric and magnetosheath ions were observed within the same 10-s spectrum but not within a single energy sweep. It is possible that time aliasing produces some of these events. However, the absence of other obvious evidence of time aliasing in the observations, along with the consistent similarity of the spectra to the expectations, argue that in these events also the dense plasmasphere material participates in dayside reconnection. These suggestive but inconclusive events are marked with "Msh&PS?" in Table 1.

In Figure 4a, a summary chart of the 57 events is shown, where the number of "Msh&PS*" and "Msh&PS?" events are represented in areas covered with dots and diagonal lines, respectively. Fourteen of the 20 events marked "Msh&PS?" or "Msh&PS*" were clear probable candidates matching on of the predicted distributions. Of the 14 clear probable candidate events, half had IMF B_Y measurement available (Figure 4b). In the rest of 20 events, odd-shaped distributions were observed that did not agree with any of the predicted spectra. In the seven cases with available IMF information, six showed observed ion distributions that are consistent with the predictions (Figure 4c). Only one case disagreed with the prediction of the reconnection model.

In addition to 20 "Msh&PS" events, we found several examples of double-peaked ion distributions in which both peaks had magnetosheath-like energy within the LLBL. We speculate that these may be due to a multiple reconnection process, but these very interesting distributions are beyond the scope of this paper.

In summary, evidence is clearly found that during times of strong magnetopause compression and erosion the draining plasmaspheric ions and entering magnetosheath ions can be simultaneously present on the same flux tube. Moreover, six of the seven events with available IMF data have velocity space signatures that are consistent with expectations based on the reconnection process. This demonstrates that flux tubes loaded with dense plasmaspheric material do participate in the reconnection process, a result that has significant implications regarding the fate of the draining plasmaspheric material at the magnetopause and, indeed, regarding the parameters controlling the operation of dayside reconnection. Our study supports the suggestion that plasmaspheric material present in reconnecting flux tubes should be transported toward the tail of the magnetosphere, potentially contributing to the plasma sheet content [*Borovsky et al.*, 1997a]. It therefore does not explain why the search for draining plasmaspheric plasma on polar cap field lines with measurements from the Polar satellite has, so far, been unsuccessful [e.g., *Borovsky et al.*, 1997b]. The fact that draining plasmaspheric ions may be energized by the reconnection process to a level comparable with the energy of the magnetosheath population, making the plasmaspheric ions difficult to identify, is one possible explanation. This may also be the reason why few Msh&PS events were found in our 8-year data set.

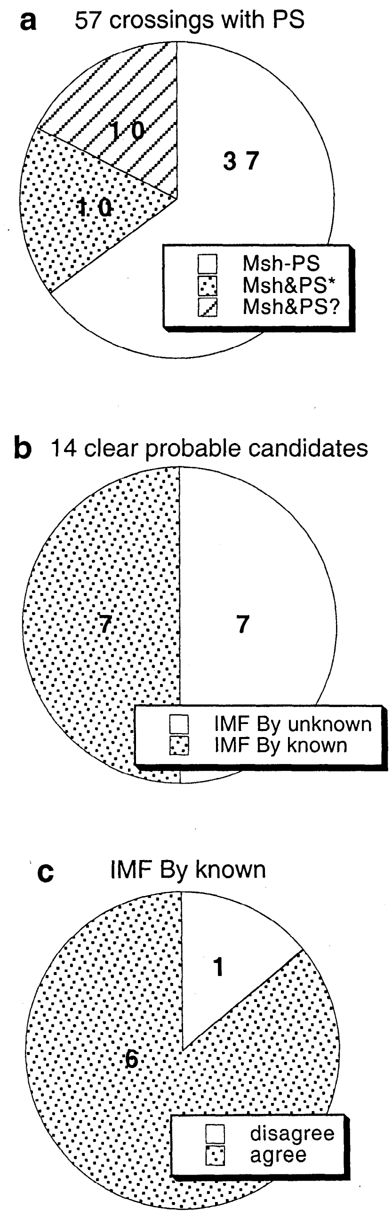

Figure 4. Pie charts for (a) 57 events where magnetosheath ions are adjacent to plasmaspheric ions, (b) 14 clear probable "Msh&PS" events, and (c) seven "Msh&PS" events with available IMF B_Y. See text for detailed descriptions.

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